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Wissenstransfer
par excellence

WS-Policy

Ein Standard mit Schwächen

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Agenda

- Web Services
- Quality of Service
- WS-Policy
  - Assertions and Operators
  - Runtime Behavior
- Applying WS-Policy
  - Increasing the expressivity of WSDL
  - Formal representation of Quality of Service (QoS) attributes
  - Service selection

Web Services – Basics

- Service interfaces are defined with WSDL
- Exchange of SOAP documents
- Platform independency
- Interoperability
- Extensibility towards Quality of Service

```
<s:Envelope ...>
  <s:Header>
    ...
  </s:Header>
  <s:Body>
    ...
  </s:Body>
</s:Envelope>
```

Separation of Concerns (I)

- Typically, a Web service implementation comprises
  - the core business functionality and
  - non-functional aspects such as security, fault tolerance, performance, scalability, …
- Functional and non-functional aspects should be separated:
  - increased reusability
  - reduced complexity of the implementation
  - the different aspects can evolve independently from each other
  - reduced maintenance efforts

Separation of Concerns (II)

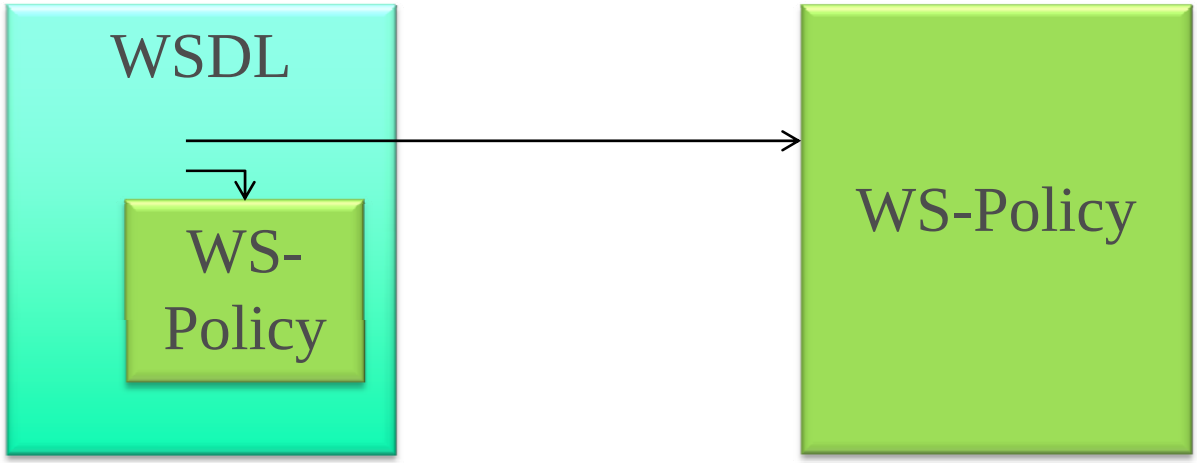
Typically in some programming language such as Java, C# ...

Ideally, specified in a declarative manner
→ Policy language

- The Web service's runtime environment is responsible for guaranteeing the specified behavior.

WS-Policy

- WS-Policy is a well-known framework for defining policies.
- W3C Recommendation: Web Services Policy 1.5 (Sep. 2007)
- Widely used and supported (Glassfish, Axis2, WCF, …)
- WS-Policy descriptions can be attached to WSDL.



WS-Policy: Assertions

- A policy is a collection of assertions.
- A single assertion may represent a capability, a requirement or a constraint.
- Every assertion has an XML representation. Examples:

```
<wsu:IncludeTimestamp/>
```

A timestamp has to be included in the message.

```
<sp:SignedElements>
  <sp:XPath>
    /S:Envelope/S:Body
  </sp:XPath>
</sp:SignedElements>
```

The body of the message must be signed.

```
<AccountingAssertion cost = "1"/>
```

The usage cost of the service is $1.

WS-Policy: Operators

- WS-Policy introduces operators to combine assertions.
- Example:

```
<wsp:Policy wsu:Id="SimplePolicy">
  <wsp:ExactlyOne>
    <wsp:All>
      <sp:IncludeTimestamp/>
      <sp:EncryptSignature/>
    </wsp:All>
    <wsp:All>
      <sp:UsernameToken>
    </wsp:All>
  </wsp:ExactlyOne>
</wsp:Policy>
```

Alternative 1

Alternative 2

Runtime Behavior

- Suppose the server policy requires `IncludeTimestamp`.
- We can distinguish two cases:
  - Case 1: The client includes a timestamp. ✓
  - Case 2: The client does not include a timestamp. ✗

```
<s:Envelope ...>
  <s:Header> ...
    <o:Security> ...
      <u:Timestamp ...>
        <u:Created>2008-12-12T15:51:08.460Z</u:Created>
        <u:Expires>2008-12-12T15:56:08.460Z</u:Expires>
      </u:Timestamp>
    </o:Security>
  </s:Header>
  <s:Body>
    <sayHelloResponse ... >
      ...
    </sayHelloResponse>
  </s:Body>
</s:Envelope>
```

Case 1

WS-Policy: Summary

- WS-Policy defines a simple language:
  - Three operators: `All`, `ExactlyOne`, `Policy`
  - Normal form for policies
- Basic buildings blocks are assertions.
- Assertions have a
  - name (its QName)
  - zero or more nested child elements
  - zero or more assertion parameters
- The semantics of assertions are defined literally. Example:
  - “The SignedElements assertion is used to specify arbitrary elements in the message that require integrity protection.”

WS-Policy – Limitations

- Limited set of operators
  - No support for conditional assertions:

    „ The content of a Web service request must be digitally signed, if the request comes from a different security domain.”

- Standardized WS-Policy assertions are available only for few domains such as Message Security and Reliable Messaging.

- Policy intersection yields counterintuitive results:
  - When checking the compatibility of WS-Policy descriptions , the proposed algorithm of WS-Policy is not suitable in many situations.

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WS-Policy – OCL Case Study

- WSDL allows the definition of interfaces of Web services in an interchangeable, XML-based format.
- Among other information, WSDL introduces the name, the parameter types and faults of a Web service.
- This information is sufficient for a service consumer to construct a *syntactically* correct Web service request.
- However, WSDL does not allow the definition of arbitrary constraints imposed by the service implementation, e.g. range restrictions on parameters:
  - void f (int i) where (0 < i) AND (i < 200)

An Example: Weather Service

- There are providers for weather data (e.g., National Weather Service, NWS, http://www.nws.noaa.gov/).
- Typically, a weather service requires a longitute and latitude both of type xsd:decimal.
  - If called with 80 and -120, the caller gets following answer/exception: „Point is not on an NDFD grid“
  - If called with 37.8 and -122.4, the current weather in San Francisco is returned.

→The expressive power of WSDL can be increased with WS-Policy and other standard technologies.

Questions and Anwers

- How to formulate constraints in a standardized manner?

  → Object Constraint Language (OCL)

- How to associate WSDL entities with OCL constraints?

  → WS-PolicyAttachment and WS-Policy

- Syntactic representation of OCL expressions?

  → OCL-Assertions for WS-Policy

- How to adapt the runtime environment to check the constraints?

  →OCL-Handler for Web services infrastructures

Object Constraint Language (OCL)

- OCL is used in combination with the Unified Modeling Language (UML) to further constrain UML models in a clear and unambiguous manner.
- In OCL, “a constraint is a restriction on one or more values of (part of) an object-oriented model or system”.
- Textual representation of the constraint expressions.
- Important OCL constructs:
  - Preconditions and postconditions
  - Invariants
  - Collections

OCL Examples

- Precondition and postcondition

```
context Math::squareRoot(Real arg)
  pre:  arg >= 0
  post: result >= 0
```

- Invariant

```
context Customer
  inv: this.age >= 0 and
       this.address.zip.size() == 5
```

OCL-Assertions for WS-Policy

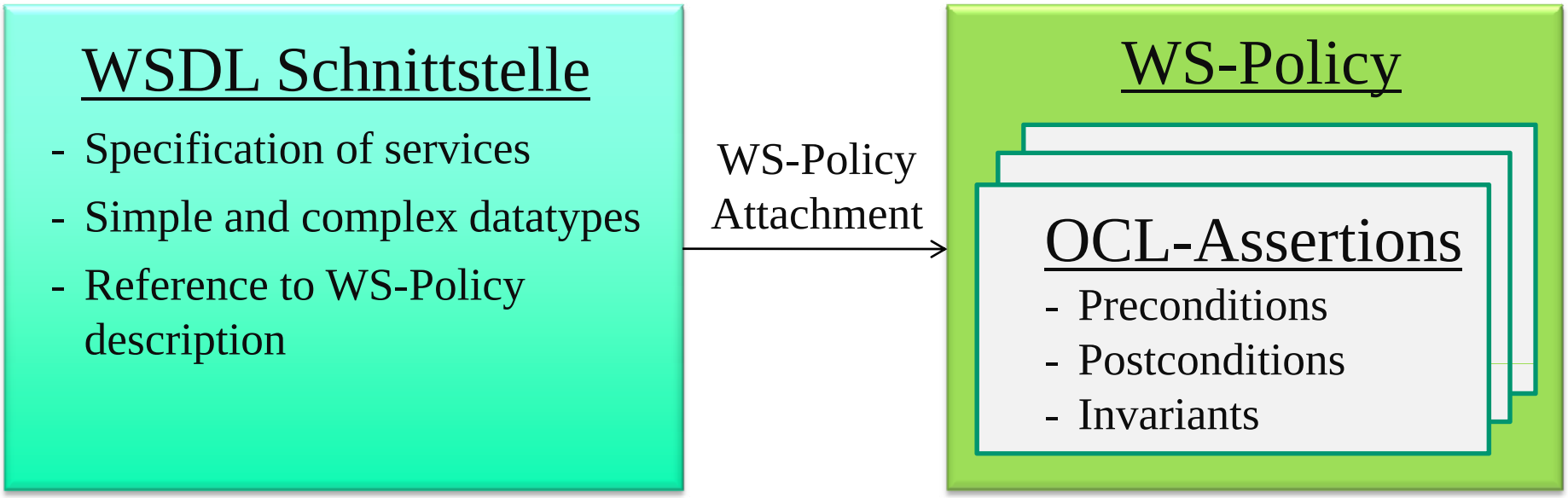
- OCL-OperationAssertion: specifies pre- and postconditions

```
<ocl:OperationAssertion Context = "NDFDgenByDay">
  <ocl:Precondition>
    longitude &gt; -130 AND longitude &lt; -59
  </ocl:Precondition>
  ...
  <ocl:Postcondition>
    result.size() &gt; 0
  </ocl:Postcondition>
</ocl:OperationAssertion>
```

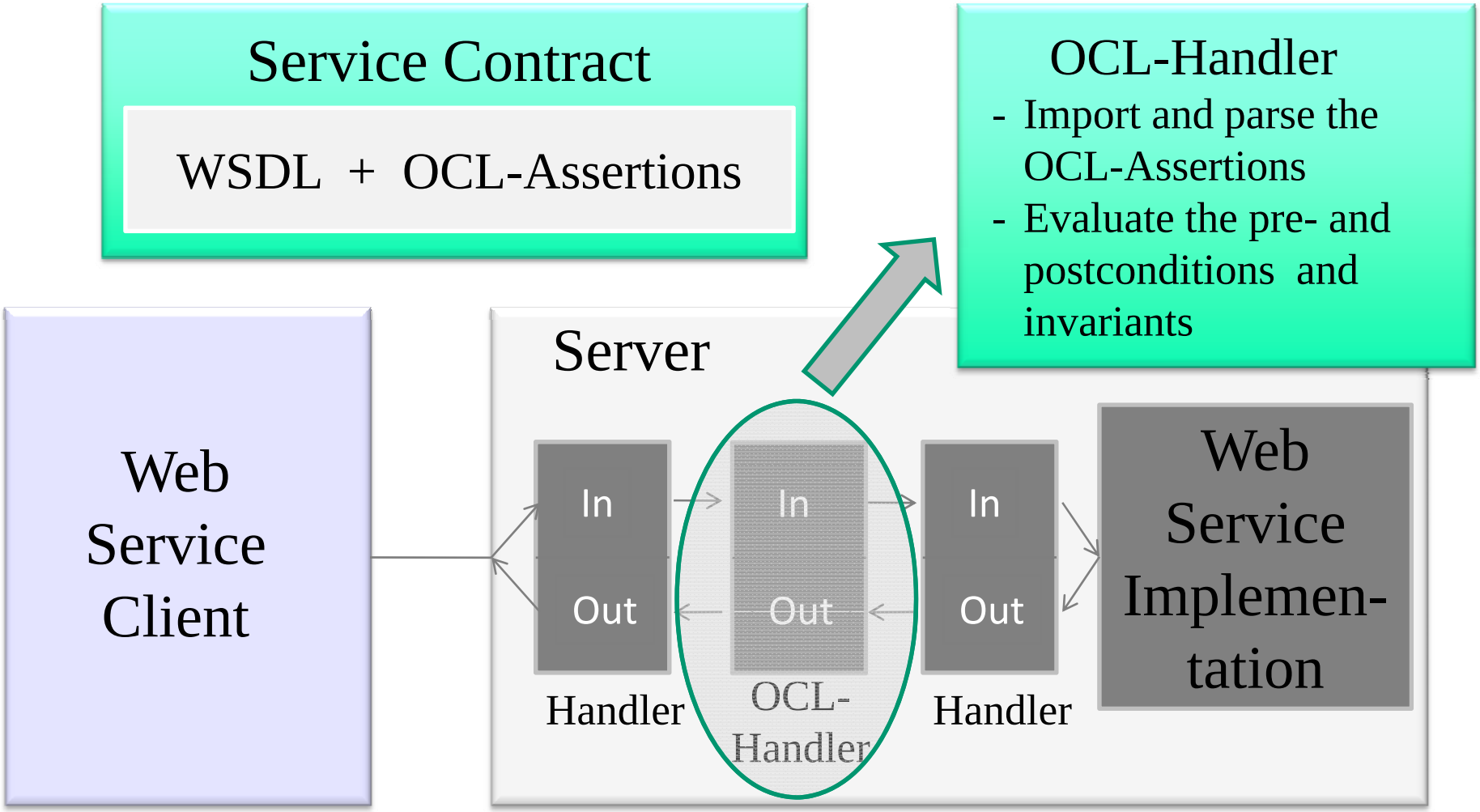
- OCL-DataAssertion: specifies invariants

```
<ocl:DataAssertion Context ="CustomerData">
  <ocl:Inv>
    this.age &gt;= 0
  </ocl:Inv>
</ocl:DataAssertion>
```

WSDL and OCL


WSDL Schnittstelle
- Specification of services
- Simple and complex datatypes
- Reference to WS-Policy description
WS-Policy Attachment
WS-Policy
OCL-Assertions
- Preconditions
- Postconditions
- Invariants

Runtime Environment



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Custom Assertions

- WS-Policy does not come with specific assertions.
- WS-* specifications (e.g. WS-SecurityPolicy) define domain-specific assertions such as `IncludeTimeStamp`.
- In many situations, it would be helpful to have a further repertoire of assertions covering specific themes such as:
  - Constraints on Web service parameters (→ OCL-Assertions)
  - A specified (average) response time will be guaranteed.
  - The usage of the service does not cost more than $1.
  - The usage costs of a Web service decreases by 10%, if the service is invoked between 10pm and 5am.

Custom Assertions: Formalization

1. Define the XML representation, e.g.

```
<PerformanceAssertion average_runtime = "1000"/>
```

```
<AccountingAssertion cost = "1"/>
```

```
<If type="TimeCondition" from="10pm" to="5am">
  <wsp:All>
    <DiscountAssertion discount="10%"/>
  </wsp:All>
</If>
```

2. Implement Java/C#/… classes that realize these assertions.
3. Extend the runtime environment such that the semantics of the assertions is respected.

Different Types of Assertions

- There are two types of custom assertions:
- Type 1:
  - A Type 1 assertion does not require that the Web service client includes additional information into the SOAP request.

  → Runtime environment must be extended only on *server* side.

- Type 2:
  - A Type 2 assertion can only be properly evaluated on server side, if the client includes further data into the SOAP header.

  → Runtime environment must be extended on *client* and *server* side.

Type 1 Assertion

- Example: OCL-Assertions
- Actions on client side:
  - The *standard Web service runtime includes* the parameter values of the service request into the body of the SOAP message.
  - There is no need to pass additional data to the server.
- Actions on server side:
  - The values of the parameters are extracted from the body of the SOAP message and passed to the OCL-Checker.
    - Constraint violation → rejection of the request
    - otherwise → delegation to the service implementation.

Type 2 Assertion

- Example: `<AccountingAssertion cost = "1"/>`
- Situation
  - Meaning of the assertion: The usage cost of the service is $1.
  - Suppose the client is willing to pay at most $0.5.

  → Contradictory requirement!
- Questions
  - Which part of the system is responsible for checking the condition?
  - Two answers:
    - Usage of a client policy.
    - Transmission of additional data to the server.

Type 2 Assertion: Client Policy

- Both server and client have their own WS-Policy descriptions.

Client Policy

```
<wsp:Policy wsu:Id="SimplePolicy">
 <wsp:All>
  <wsp:All>
   AccountingAssertion cost = "0.5"/>
  </wsp:All>
 </wsp:All>
</wsp:Policy>
```

Server Policy

```
<wsp:Policy wsu:Id="SimplePolicy">
 <wsp:All>
  <wsp:All>
   AccountingAssertion cost = "1"/>
  </wsp:All>
 </wsp:All>
</wsp:Policy>
```

- WS-Policy introduces policy intersection to check the compatibility of two policies.
- In this example: Client and server policies are not compatible.
- Requirement: Client must apply policy intersection before service invocation.

Type 2 Assertion: Transmission of Assertion Parameters

- Strategy
  - The client runtime environment puts assertion parameters into the header of the SOAP message.
  - These are retrieved and checked by the server runtime.

```
<wsp:Policy wsu:Id="ClientPolicy">
 <wsp:All>
  <wsp:All>
   AccountingAssertion cost = "0.5"/>
  </wsp:All>
 </wsp:All>
</wsp:Policy>
```

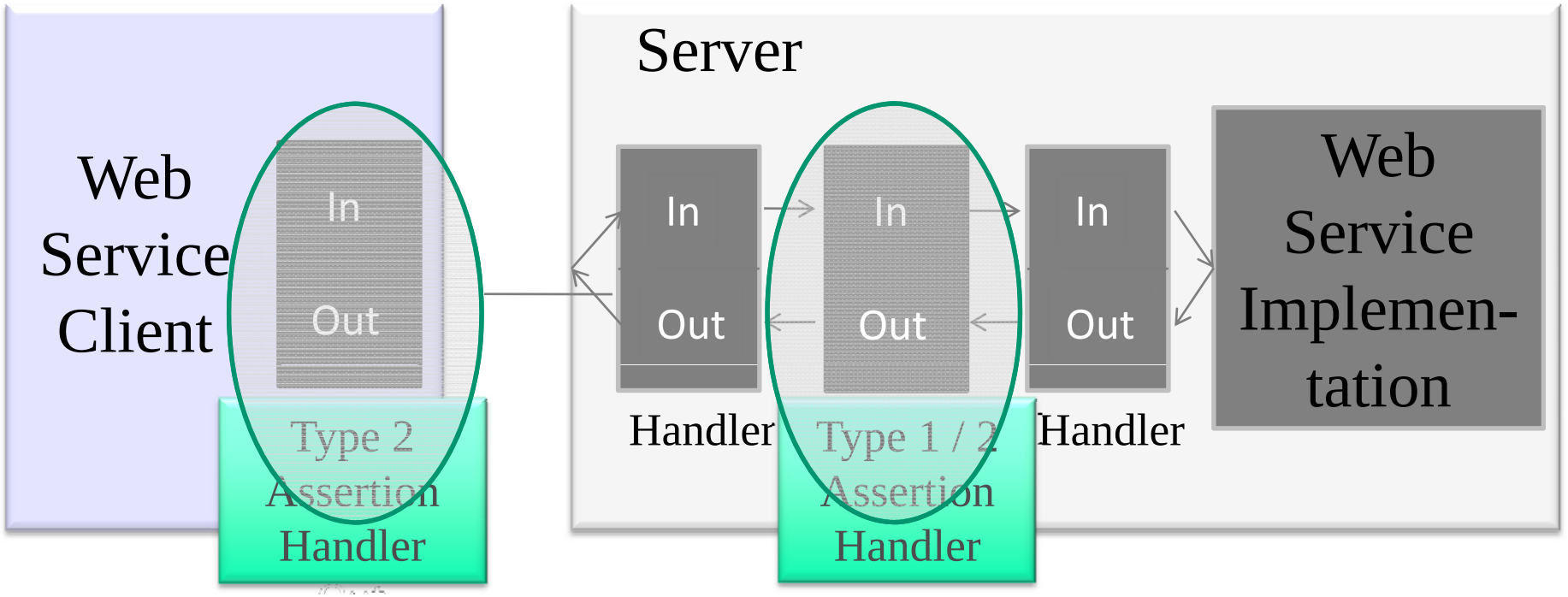
```
<wsp:Policy wsu:Id="ServerPolicy">
 <wsp:All>
  <wsp:All>
   AccountingAssertion cost = "1"/>
  </wsp:All>
 </wsp:All>
</wsp:Policy>
```

SOAP Request created by client runtime

```
<s:Envelope ...>
 <s:Header> ...
  <AccountingAssertion cost="0.5"/>
 </s:Header>
<s:Body> ... </s:Body>
</s:Envelope>
```

Contradiction detected by server runtime

Implementation Issues



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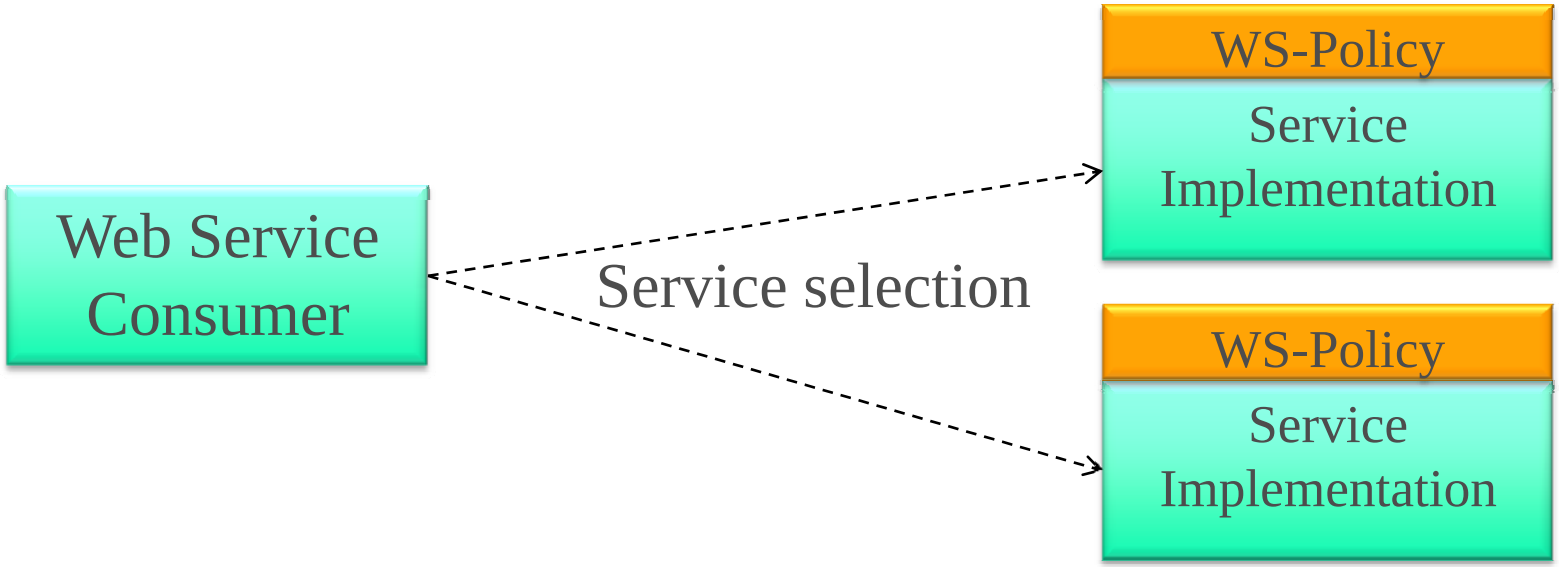
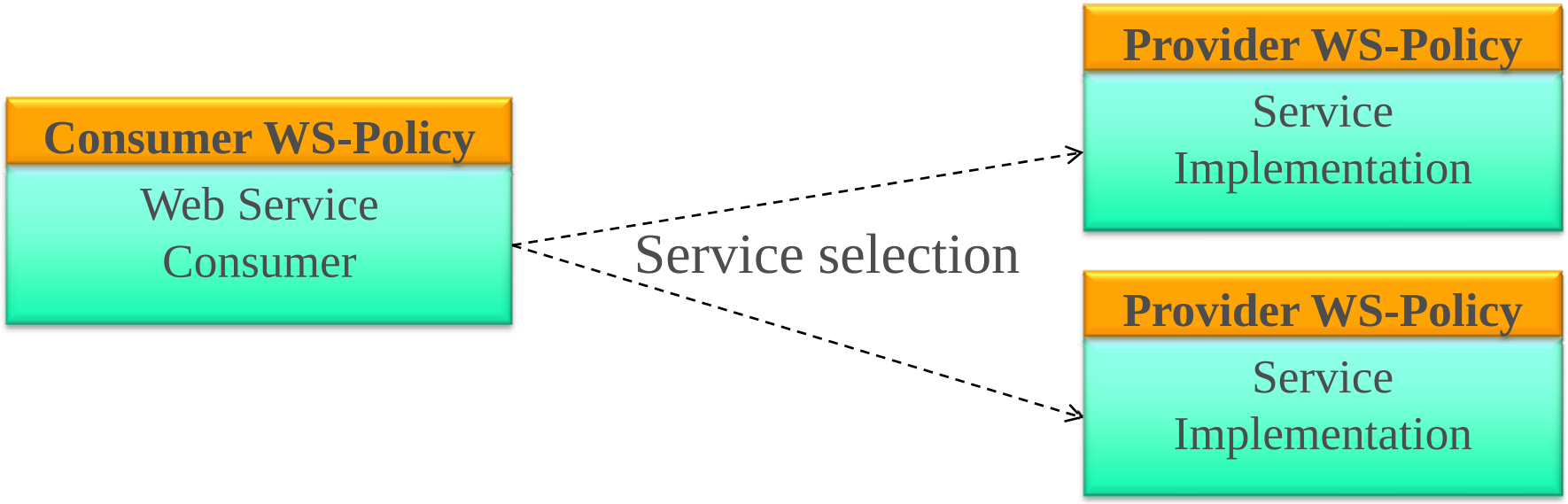
WS-Policy and Service Selection

- A WS-Policy description
  - expresses non-functional requirements in a formal manner
  - helps the Web service consumer to find an appropriate service.
- Problem: How to automate service selection?



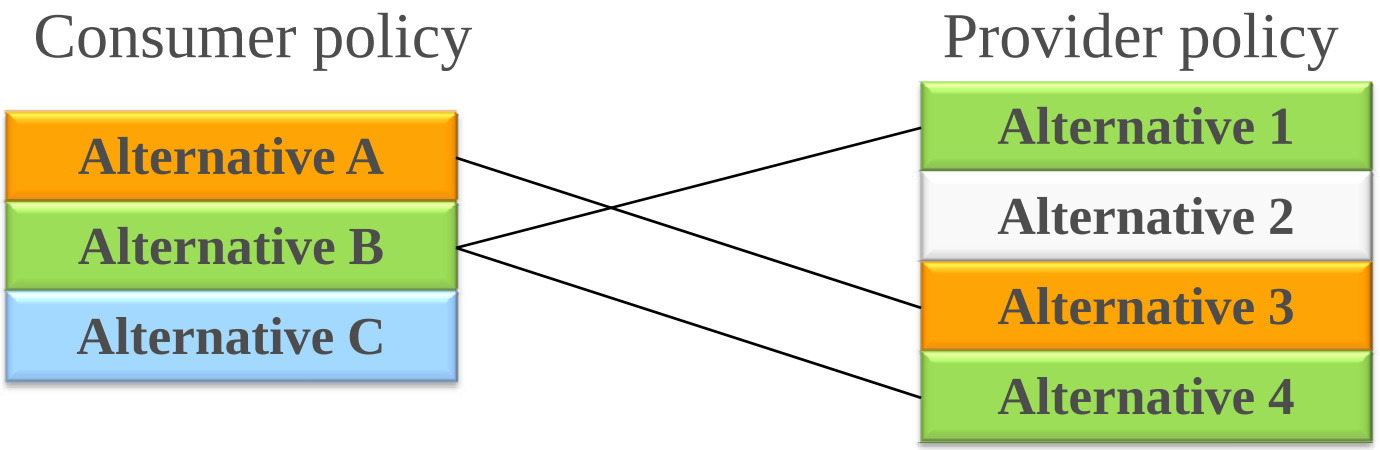
Consumer vs. Provider Policy

- Solution: Both parties have their own WS-Policy descriptions.
  - **Provider policy**:
    Conveys a set of conditions coupled with the usage of the service.
  - **Consumer policy**:
    Specifies the conditions under which he is willing to use the service



Policy Intersection

- WS-Policy defines policy intersection as a “first approximation” for determining the compatibility of policies.



A connection indicates compatible alternatives.

Policy Intersection: Examples

P1
```
<sp:SignedElements>
  <sp:XPath>/S:Envelope/S:Body</sp:XPath>
</sp:SignedElements>
```

P2
```
<sp:SignedElements/>
```

Compatible

P3
```
<wsam:Adressing>
  <wsp:Policy/>
</wsam:Adressing>
```

P4
```
<wsam:Adressing/>
```

Incompatible

P5
```
<AccountingAssertion cost = "1"/>
```

P6
```
<AccountingAssertion cost = "0.5"/>
```

Compatible

→ Policy intersection may produce counterintuitive results.

Policy Intersection: Problems

- Policy intersection
  - is a purely syntactic approach
  - does not incorporate the semantics of assertions
  - ignores parameters of assertions
  - synonymous assertions are considered incompatible.
- Currently, there is no uniform approach that combines both the domain-independent intersection and domain-specific processing.

→ Policy Entailment: new approach for checking the compatibility of WS-Policy descriptions

Policy Entailment: The Idea (I)

- Example:
  - Assertion A1: `<AccountingAssertion cost = "1"/>`
  - Assertion A2: `<AccountingAssertion cost = "0.5”/>`
  - A1 entails A2 because: if someone is willing to pay $1 for the usage of a particular service, then he is also willing to pay $0.5 (but not vice versa).

Policy Entailment: The Idea (II)

- Define a binary relation between the assertions, which reflects the intented semantics of the assertions, e.g.

  Assertion a: `<IncludeTimestamp/>`

  Assertion b: `<AccountingAssertion cost = "1"/>`

  Assertion c: `<AccountingAssertion cost = "0.5"/>`

  a < a, b < b, c < c, b < c

- Definition of Policy Entailment and Policy Differencing.
- Formal and algorithmic foundations are described in
  - Bernhard Hollunder: Domain-Specific Processing of Policies or: WS-Policy Intersection Revisited; International Conference on Web Services (ICWS 2009).

Summary

- WS-Policy is well-known and widely used standard.
- Framework for defining policies
  - Small set of operators
  - Extensibility through custom assertions
  - Integration with other technologies such as WSDL through WS-PolicyAttachment
  - Small set of standardized assertions
  - Counterintuitive results of policy intersection
- Multipurpose framework
  - Increasing the expressivity of WSDL
  - Formal representation of Quality of Service attributes through custom assertions

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Vielen Dank!

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